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## ALUMINIUM PRODUCTION PROCESS

The present invention relates to a process for producing aluminium and aluminium-containing materials.

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The term "aluminium-containing materials" includes by way of example, alumina, aluminium hydroxide, aluminium chloride, and aluminium trihydrate.

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The Bayer process for producing alumina from aluminium-containing feed materials such as bauxite and the Hall-Heroult process for electrolytically producing aluminium from alumina is the only commercially significant process route for producing aluminium metal from aluminium-containing feed materials. This process route is also used to produce alumina and aluminium hydroxide for other applications.

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However, whilst the above process route is efficient, it has disadvantages of high capital costs, being suitable only for high grade bauxite, and the aluminium metal and other aluminium-containing materials produced are only of moderate purity, albeit suitable for most current product needs.

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The present invention provides an alternative process for producing aluminium and aluminium-containing materials from aluminium-containing feed materials.

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The present invention is based on the realisation that (a) recently discovered organic reagents that are suitable for a solvent extraction process to extract aluminium ions from an aqueous liquor into an

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aluminium complex and (b) an electrolytic cell based on an ionic liquid electrolyte for producing aluminium directly or indirectly from the aluminium complex is a basis of an alternative process for producing aluminium from  
5 aluminium-containing feed materials.

According to the present invention there is provided a process of producing aluminium and aluminium-containing materials from a solid aluminium-containing  
10 feed material that comprises:

- (a) leaching the aluminium-containing feed material with a leach liquor and forming an aqueous solution containing aluminium ions;  
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- (b) extracting aluminium ions from the aqueous solution by contacting the aqueous solution with an organic reagent and loading aluminium ions onto the organic reagent and forming an aluminium complex; and  
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- (c) recovering aluminium or an aluminium-containing material from the aluminium complex.

25 The organic reagent may be any suitable complexing ligand, compound, polymer or ion exchange resin.

Suitable organic reagents are described by way  
30 of example in International application PCT/AU02/00243 in the name of Technological Resources Pty. Limited.

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There are a number of possible options for recovery step (c).

5 The aluminium-containing material may comprise, by way of example, alumina, aluminium hydroxide, aluminium trihydrate, and aluminium chloride in any suitable solid form.

10 One option for recovery step (c) comprises displacing aluminium ions from the aluminium complex by contacting the aluminium complex with an aqueous solution and thereafter recovering aluminium or an aluminium-containing material.

15 The solution used in step (c) may be a more acidic solution than the initial leach liquor used in step (a) and have limited solubility for aluminium such that the aluminium ions are displaced from the aluminium  
20 complex and immediately precipitate as a solid aluminium-containing material, for example as alumina and/or aluminium hydroxide, and the solid material is thereafter recovered.

25 The solution used in step (c) may be an acidic solution such that the aluminium ions are displaced from the aluminium complex into solution and are thereafter recovered from solution.

30 Preferably the solution is a hydrochloric acid solution.

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Preferably the hydrochloric acid solution has a pH of 1-6.

5 In such a situation, by way of example, a solid aluminium-containing material in the form of alumina or aluminium hydroxide may be recovered from the solution by heating the solution and causing thermal dissociation to drive off water and hydrochloric acid in gaseous forms and produce alumina in a powder form.

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The alumina or aluminium hydroxide or other aluminium-containing materials that are precipitated directly from the aluminium complex or are precipitated from the solution as described above may be sold as a product or processed further to produce aluminium using the conventional Hall-Heroult process or other processes, such as processes described hereinafter.

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The solid aluminium-containing materials, particularly alumina and aluminium hydroxide, may be advantageously produced with an extremely fine particle size and high purity to increase its value when used directly in applications such as making ceramics and fire retardant composite materials.

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Alternatively, aluminium may be recovered from the solution used in step (c) by transferring aluminium ions into an ionic liquid and thereafter recovering aluminium from the ionic liquid.

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The term "ionic liquid" is understood to herein to mean a liquid that substantially consists of ions and can be used in a temperature range of 0-100°C.

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Preferably the process comprises recovering aluminium from the ionic liquid by applying a potential across an anode and a cathode positioned so that at least  
5 the cathode is in contact with the ionic liquid and depositing aluminium on the cathode.

The transfer of the aluminium ions into the ionic liquid may be directly from the solution into an  
10 ionic liquid in the same compartment.

In such a situation, preferably the ionic liquid is hydrophobic with a high affinity for aluminium and is stable in the presence of water.  
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The transfer of the aluminium ions into the ionic liquid may also be indirectly from the solution.

For example, the transfer may be from the  
20 solution contained in one compartment into the ionic liquid contained in another compartment via a membrane, diaphragm or other suitable means that is permeable to aluminium ions and separates the compartments.

In this arrangement the driving force for the transfer of aluminium ions from the compartment containing the solution to the other compartment containing the ionic liquid can be either by concentration gradient or by having the anode in the aqueous compartment and the  
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30 cathode in the ionic liquid compartment.

Preferably the membrane, diaphragm or other suitable means that is permeable to aluminium ions is resistant to attack by the solution and the ionic liquid

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and is impermeable to other constituents of the solution and the ionic liquid.

Alternatively, the process may comprise  
5 producing the alumina or aluminium hydroxide or other  
aluminium-containing materials precipitated directly from  
the aluminium complex or from the solution as described  
above in a solid form and thereafter dissolving the solid  
material in the ionic liquid directly or indirectly and  
10 recovering aluminium from the ionic liquid as described  
above.

Another, although by no means the only other,  
possible option for recovery step (c) comprises displacing  
15 the aluminium ions directly from the aluminium complex by  
transferring aluminium ions into an ionic liquid  
and thereafter recovering aluminium from the ionic liquid,  
for example electrolytically as described above.

20 The process allows the use of a wide range of  
aluminium-containing materials as feed materials,  
including currently difficult-to-treat impure dross and  
waste materials from smelters, and can produce higher  
purity aluminium as a value added product for use in  
25 specialist applications such as capacitors and compact  
discs.

The present invention is described further by  
way of example with reference to the accompanying  
30 flowsheet of one embodiment of the process of the  
invention.

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The process shown in the flowsheet is suitable for producing aluminium from a wide range of aluminium-containing feed materials such as bauxite, kaolin, dross, and desilication products.

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With reference to the figure, the key steps in the embodiment of the process are as follows.

1. Leaching aluminium-containing feed material.

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This step comprises leaching aluminium from a suitable feed material, for example bauxite, and forming an aqueous solution containing aluminium ions.

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Typically, leaching is accomplished using a leach liquor comprising a caustic liquor at high pH or a dilute acid at pH 3-4.

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Because the aluminium is subsequently recovered by solvent extraction, as described below, the leaching step does not have to be at high temperatures and pressures. Specifically, there is no requirement to achieve supersaturation to promote subsequent precipitation. This leaves open a much wider operating range of dissolution conditions, especially when using non-bauxitic feed materials.

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2. Extraction.

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This step comprises extracting aluminium from the leach solution using an organic reagent of the type described in International application PCT/AU02/00243.



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The aluminium is selectively extracted and forms an aluminium complex, thereby avoiding issues of purification.

5     3.            Aluminium stripping

This step comprises stripping aluminium from the aluminium complex, ie the loaded organic phase containing the aluminium ions, by contacting the aluminium complex  
10 with a suitable solution.

One option is to carry out this step using a solution that is more acidic than the initial leach liquor (and may be neutral or slightly basic) and has low  
15 solubility for aluminium, whereby the aluminium is displaced from the aluminium complex and precipitates immediately as a solid aluminium-containing material.

Another option is to carry out this step using a  
20 moderate strength hydrochloric acid solution, whereby the hydrogen ions displace the aluminium from aluminium complex, with the result that the aluminium transfers to the hydrochloric acid solution and regenerates the organic reagent. The regenerated organic reagent can be recycled  
25 to extract more aluminium.

Another option is to directly transfer the aluminium from the aluminium complex into an ionic liquid electrolyte.  
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4.            Aluminium recovery.

One option to recover aluminium from the



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hydrochloric acid solution is to use thermal dissociation to drive off water and hydrochloric acid leaving a pure alumina powder for sale as a product and/or for use in electrolysis cells to produce high purity aluminium.

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Another option to recover aluminium from the hydrochloric acid solution is to transfer the aluminium from the hydrochloric acid solution into an ionic liquid electrolyte and produce high purity aluminium metal via electrolysis of aluminium ions in the ionic liquid.

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The form of the electrolysis step depends in part upon the nature of the ionic liquid used.

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One approach with this option is to use a cell which is set up so that aluminium transfers from the aqueous acidic solution into the ionic liquid through an ion selective membrane.

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Another approach with this option is to use a hydrophobic ionic liquid with a high affinity for aluminium that is stable in the presence of water and acid whereby the aluminium transfers into the ionic liquid directly. This approach may be assisted by adding chemical additives to the ionic liquid to improve the aluminium affinity of the ionic liquid. Chemical additives include, by way of example, complexing reagents to improve the aluminium affinity of the ionic liquid.

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Another option is to separate the aluminium in the form of a solid aluminium-containing material such as alumina, aluminium trihydrate and/or aluminium chloride and dissolve the solid material into the ionic liquid to provide the source of aluminium.

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The reaction at the electrolysis cell cathode produces aluminium metal. The corresponding anode

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reaction most probably generates chlorine gas or oxygen. The chlorine gas could be recycled to the process after conversion to hydrochloric acid and the oxygen that could be captured as a separate product.

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The above-described electrolytic recovery of aluminium for the ionic liquid containing aluminium ions also applies to recovering aluminium from ionic liquid containing aluminium ions derived directly from the aluminium complex.

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Many modifications may be made to the embodiment of the present invention described above without departing from the spirit and scope of the invention.